that the alloys Nos. 7018a to 7029a and Nos. 13001a to 13006a are identical in composition with the aforesaid copper alloys Nos. 7018 to 7029 and Nos. 13001 to No. 13006, respectively.

[0069] Seventh invention alloys Nos. 7018a to 7029a were subjected to wear resistance tests in comparison with conventional alloys Nos. 13001a to 13006a.

[0070] The tests were carried out in this manner. Each extruded test piece thus obtained was cut on the circumferential surface, holed, and cut down into a ring-shaped test piece 32 mm in outside diameter and 10 mm in thickness (that is, the length in the axial direction). The test piece was then fitted and clamped on a rotatable shaft, and a roll 48 mm in diameter placed in parallel with the axis of the shaft was thrust against the test piece under a load of 50 kg. The roll was made of stainless steel having the JIS designation SUS 304. Then, the SUS 304 roll and the test piece put against the roll were rotated at the same number of revolutions/minute – 209 r.p.m., with multipurpose gear oil being dropping on the circumferential surface of the test piece. When the number of revolutions reached 100,000, the SUS 304 roll and the test piece were stopped, and the weight difference between before rotation and after the end of rotation, that is, the loss of weight by wear, mg, was determined. It can be said that the alloys which are smaller in the loss of weight by wear are higher in wear resistance. The results are given in Tables 34 to 36.

[0071] As is clear from the wear resistance test results shown in Tables 34 to 36, the tests showed that those seventh invention alloys Nos. 7018a to 7029a were excellent in wear resistance as compared with not only the conventional alloys Nos. 13001a to 13004a and 13006a but also No. 13005a, which is an aluminum bronze most excellent in wear resistance among expanded copper designated in JIS. From comprehensive

considerations of the test results including the tensile test results, it may safely be said the seventh invention alloys are excellent in machinability and also possess a high strength feature and wear resistance equal to or superior to the aluminum bronze which is the highest in wear resistance of all the expanded copper alloys under the JIS designations.

Example 3

[0072] In yet another series of tests, first and third invention alloys were examined for impact resistance. Then tin was added to these first and third invention alloys to show the affect of tin on the copper alloys of the present invention.

[0073] In general, mechanical property standards for metals, such as tensile strength, elongation, proof stress, hardness and others, are specified under JIS and ASTM standard. However, a measurement of metal impact resistance, such as the Charpy impact value, is not so specified under these standards. However, there are metal products that need to be impact resistant. For example, some products undergo a cutting process followed by a caulking process during manufacture, which requires that the metal material be impact resistant. Relevant product examples include tube connectors called "nipples, metal hinges for furniture, automobile sensors, and the like. To determine the impact resistance of the copper alloys of the present invention and to show that tin should be excluded from the alloys of the present invention, the Charpy impact test is used.

[0074] Table 9 includes impact resistance data collected on the copper alloys of the present invention and shows how the addition of tin to the alloys of the present invention adversely affects the impact resistance of the alloys of the present invention. Specifically, test pieces of identical size and shape were evaluated for impact resistance by conducting the

Charpy impact test using the test machine specified under Japanese Industrial Standard (JIS) B 7722 in accordance with the standard testing method specified under JIS Z 2242. This test corresponds to International Standard ISO R 83, and is also specified under ASTM E23 in the United States. Hence, the Charpy impact test is widely known as will be appreciated by one skilled in the art.

[0075] The Charpy impact test demonstrates the degree of resistance a material has against a dynamic impact. The test generates an "impact value" in Joules/cm (J/cm) from which the toughness and the brittleness of a metal is assessed. In Table 1, copper alloys 1 and 4 are first invention alloys, whereas copper alloys 3 and 6 are third invention alloys. It is noted that the third invention alloys have the highest impact values and are the most suitable material for making nipples. However, when even a small amount of tin is added to the copper alloys of the present invention, such as about one percent, by weight, the impact value diminishes greatly. Therefore, it is a feature of the copper alloys of the present invention that each is substantially tin free. In other words, the copper alloys of the present invention, having a high degree of impact resistance, contain essentially no tin.

ALLOY COMPOSITION CONSTRAINT FORMULA

[0076] Another feature of the copper alloys of the present invention is that each copper alloy composition is constrained by the general formula relationship

(1) $60 \leq X - 3Y + a_o Z_o \leq 70$

where X is the percent, by weight, of copper; Y is the percent, by weight, of silicon; and $a_o Z_o$ represents the contribution to the relationship of elements other than copper, silicon and zinc. In other words, the relationship described by the alloy composition constraint formula (1) is required to make copper alloy compositions with the advantages